A Cooperative Project between the U.S. Environmental Protection Agency and PWB Manufacturers Nationwide

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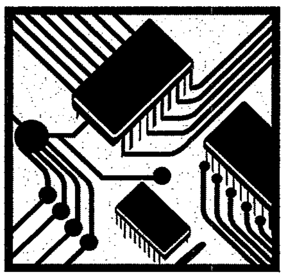
design FOR THE ENVIRONMENT

PRINTED WIRING BOARD CASE STUDY 4

Design for the Environment U.S. EPA

PRINTED WIRING BOARD PROJECT



Plasma Desmear: A Case Study

Waste. To a manufacturing operation, waste points to parts of the production process where resources are not being fully utilized, where money is lost, and, in many cases, where an environmental burden is generated. Like most companies, the management of Circuit Center, Inc. (CCI), a manufacturer of double-sided and multilayer printed wiring boards (PWBs), is always looking for ways to reduce the waste the company generates. And their efforts to improve their environmental performance go beyond waste reduction. They seek reductions in toxic materials used, occupational hazards, and toxic byproducts generated.

Several years ago, CCI's efforts led them to examine their desmear operations. With waste disposal related to this process accounting for over 13% of the plant's environmental management costs, their permanganate desmear process was a likely target for investigation. At the same time, process engineers were examining product quality problems related to their permanganate line. After some research into techniques for improving the efficiency of their permanganate process, CCI's focus turned to not just improving the line, but replacing it with a completely different desmear technology called the plasma process. CCI's research indicated that, by using a plasma desmear, they could reduce the waste from this process dramatically (thereby reducing costs) and improve product quality. With further investigation, the company decided to give it a try. In this case study, they share their experience in implementing their plasma desmear process.

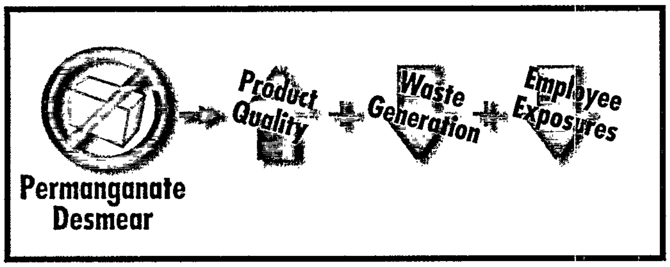
What is the Design for the Environment (DfE) Printed Wiring Board Project?

Representatives of the printed wiring board industry and other stakeholders entered into a partnership with the Environmental Protection Agency (EPA) called the Design for the Environment PWB Project. This is a cooperative, non-regulatory effort where EPA, industry, and other interested parties are working together to develop technical information on pollution prevention technologies specific to the PWB industry. This information includes comparative data on the risk, performance, and cost of alternative manufacturing options.

To date, the DfE Project has focused on conducting a comprehensive evaluation of alternative technologies for making through-holes conductive. By publishing the results of these evaluations, DfE is able to provide PWB manufacturers with the information they need to make informed business decisions that take human health and environmental risk into consideration, in addition to performance and cost. The Project is also identifying and publicizing other pollution prevention opportunities in the industry through the development of PWB case studies such as this one.

Why Pollution Prevention?

Located in Dayton, Ohio, Circuit Center, Inc., manufactures approximately 375,000 surface square feet of printed wiring board annually. With 130 employees, CCI specializes in small quantity orders of primarily prototype boards. The nature of this market requires that they routinely process many types of substrates. In the 1980s, CCI started pursuing pollution prevention opportunities more aggressively. Through some initial successful projects, they found that preventing pollution, rather than treating wastes after they were created, not only improved the environment, but could also improve their product quality and bottom line.



CCI Benefits from Eliminating Permanganate

One of their early pollution prevention efforts was to replace their electroless copper line with a formaldehyde-free, non-copper direct metallization line. Although they are a relatively small shop, they were able to justify this type of capital-intensive project through savings from their reduction in chemical use, waste treatment costs, water use, and their improved product quality.

Investigating the Desmear Process

With the change to direct metallization successfully completed, CCI process engineers were able to concentrate on other parts of the manufacturing process. After the electroless line was replaced with the more efficient direct metallization process, it became clear the heavy copper deposition of the electroless copper process had been masking manufacturing inconsistencies caused by the permanganate desmear. These inconsistencies, especially pink ring and voids, were a particular problem on panels with high aspect ratios. In addition to uncovering quality issues, the clean and efficient direct metallization line also highlighted the waste associated with the neighboring permanganate line. It was clear that changes had to be made to the desmear process to improve quality and to reduce waste.

The Most Common Desmear Technique

Smear is caused by the heat generated during drilling, which can melt the resin, depositing it on the interconnects as the drill bit retracts from the hole wall. This smear has to be removed to provide good plating adhesion to the epoxy, glass, and copper constituents of a drilled hole.

CCI had been using a permanganate-based process, the most common desmear method, which typically consists of three process baths:

1) An alkaline solvent swell facilitates the subsequent removal of the epoxy-resin smear. The chemistry of this bath is usually proprietary, but often contains n-methyl pyrrolidone, which is highly flammable and a skin and eye irritant.

2) A permanganate bath in an alkaline solution heated to 160°F or higher removes the drill smear. This bath contains sodium or potassium permanganate in a sodium hydroxide solution. The occupational health and safety concerns lie in the high temperature and caustic nature of this bath.

3) An acidic neutralizer, often a sulfuric acid-based chemistry, removes all traces of alkalinity and the oxidizer from the surface and through-holes. Sulfuric acid is a strong irritant to the nose, lungs, and skin.

Permanganate Waste Generation

Permanganate desmear waste volumes vary from one facility to the next; however, they are often a significant portion of a facility's waste stream. For example, when CCI examined their annual desmear-related disposal costs, they found that costs totaled over $40,000: quite significant (13%) for a facility with overall annual environmental management costs of $300,000.

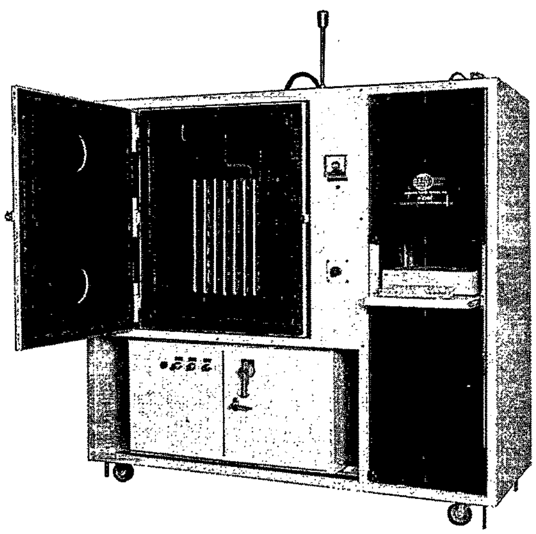
A Costly Process

Other costs associated with the permanganate process include chemical purchases, energy for the bath pumps and heaters, extensive labor for testing and maintaining the process baths within the required parameters, and water costs. In some parts of the U.S., the costs of water used for the rinses between baths can be a significant operating expense. For example, one larger facility (producing 1.8 million surface ft^2 PWB per year) uses over 3 million gallons of water annually for their permanganate rinses alone. The table on the next page shows the breakdown of the permanganate-related waste disposal costs for CCI.

Permanganate Desmear Waste Generation			
Process Bath	**Waste Contents**	**Annual Quantity Generated**	**Annual Costs for Treatment and Disposal**
Hole Swell Bath	glycol ethers mixture (30%)	592 gal	$14,685
Permanganate Bath	potassium permanganate solution	640 lb	$582
Neutralizer Bath	hydrazine mixture	112 gal	$5,085
Rinse water	rinse water and bath dragout	405,660 gal	$20,227
Total			**$40,579**

Plasma Possibilities

With the direct metallization line exposing the problems associated with the permanganate desmear process, CCI worked toward improving the efficiency of their desmear line. However, they found that even with daily lab testing and more frequent operator monitoring of the desmear baths, they were still experiencing process inconsistencies and waste. They then turned their attention to the plasma desmear process.



Plasma Desmear Unit

The Plasma Technology

Unlike the permanganate series of wet chemical tanks, the plasma desmear process takes place in a compact, sealed chamber. Panels are loaded on a rack and placed in the chamber where a vacuum is drawn. Using a radio frequency (RF) energy generator, a gas plasma is formed that contains chemically active ions or radicals. A mixture of tetrafluoromethane and oxygen is used as the reactive gas. The radicals react with the polymer smear on the board, breaking the polymer into water vapor, carbon dioxide, and hydrofluoric acid, all of which are volatile and vaporize at the low pressure. Because the reaction takes place in a vacuum, only small amounts of process gases are needed to get efficient reaction rates. The amount of hydrofluoric acid (HF) gas generated, therefore, is proportionally small and is generated in a closed system, minimizing potential exposures. Also note that the HF gas is a process byproduct and is only generated when the reaction is taking place. However, in the event of a malfunction, it is possible that the HF could be released. It is critical, therefore, that the equipment be properly and professionally installed.

In contrast to the open, heated baths of the permanganate process, occupational health and safety issues associated with the enclosed plasma process are greatly reduced. It should be noted, however, that the tetrafluoromethane gas is toxic by inhalation. The small amount of hydrofluoric acid generated by the process is toxic by inhalation and ingestion and is highly corrosive. Equipment manufacturers do offer the option of an alkaline wet scrubber to neutralize the hydrofluoric acid gas produced. The scrubber can be equipped with a pH meter to indicate to the operator when additional alkaline solution should be added.

Plasma Cost Savings

Working with a plasma equipment manufacturer to identify the system that would best meet their needs, CCI installed a plasma desmear unit in the fall of 1992. As soon as the system was in production, CCI noticed a dramatic reduction in incidences of pink ring and wedge voiding, and, consequently, in desmear-related scrap.

While the savings associated with quality improvements alone were significant, CCI also saw cost savings resulting from the elimination of wastewater treatment, water use, and off-site hazardous waste shipments associated with desmear. Additionally, operating costs were reduced.

All operators received training on using the system computer to select the appropriate run cycle for the job and on loading boards and handling hot racks. After the operators became accustomed to the system, operating costs for desmearing (for the chemistry and processing time) decreased from $0.15/ft^2$

with permanganate to $0.11/ft^2 with the plasma system. CCI engineers also point to the labor savings associated with the reduced need for maintenance, daily lab testing, waste treatment, and constant tinkering to keep the permanganate chemistries within the required parameters.

Although a quantitative energy analysis has not been conducted, plant engineers estimate that the energy used for the plasma desmear RF generator is approximately the same as that used for permanganate bath pumps and heaters. Equipment manufacturers estimate the energy cost is approximately \$0.02/ft^2. Overall, plant managers and engineers are confident that the plasma system is significantly more cost-effective than the permanganate chemistry for desmearing holes.

Other benefits that are not easily quantified, but that should also be taken into consideration, include overall reduced worker exposure, lower environmental liability, and the space-saving compact packaging of the plasma units.

Advantages of Plasma Desmear

- Improves product quality through better control and consistency of the desmear process.
- Eliminates water use and wastewater treatment.
- Reduces operating costs.
- Can effectively desmear Teflon® substrates.

But Will It Work For Me?

While many facilities agree that the environmental and product quality improvements of plasma desmear are significant, larger facilities have expressed some doubts regarding throughput issues. Where lower throughput shops do not have an issue with the system cycle time (estimated to be 11 - 15 minutes per load), larger facilities may. Conversations with larger facilities currently using plasma desmear indicate, however, that throughput is not a problem. Plasma system manufacturers provide a range of unit sizes. Systems with larger chamber size, larger power sources, or additional units are recommended to accommodate higher throughput.

The capital costs of a plasma desmear unit vary depending on both throughput requirements and the number of equipment options purchased. Typically, the capital costs range from \$65,000 to \$150,000. Options may include higher frequency RF generators to reduce cycle time, software options, a wet scrubber, or built-in analytical equipment.

While this case study describes one facility's success with plasma desmear, it may not be the best choice for every facility. Each individual manufacturer must consider its specific conditions to determine the most appropriate technology for their facility.

For More Information on Plasma...

Contact the manufacturers of plasma systems specifically designed for PWB desmear operations directly for more information. The DfE Project partners identified the following two companies as vendors of plasma equipment:

Advanced Plasma Systems, St. Petersburg FL
Phone: 813-573-4567
Plasma Etch, Huntington Beach, CA
Phone: 714-843-5944

Acknowledgments

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Additional Pollution Prevention Resources for the PWB Industry

In addition to this case study, the DfE PWB Project has prepared other case studies that examine pollution prevention opportunities for the PWB industry. All case studies are based on the experiences and successes of facilities in implementing pollution prevention projects. The other case study topics available include:

Pollution Prevention Work Practices
On-site Etchant Regeneration
Acid Management and Recovery

These case studies, and other documents published by the DfE Project, are available from:

Pollution Prevention Information Clearinghouse (PPIC)
U.S. EPA 401 M Street, SW (3404)
Washington, DC 20460
Phone: 202-260-1023 Fax: 202-260-0178
e-mail: PPIC@epamail.epa.gov

The DfE Program welcomes your feedback. If you have implemented any of the ideas in this series of PWB case studies, please tell us about it by calling the DfE Program at 202-260-1678 or via email at oppt.dfe@epamail.epa.gov.

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